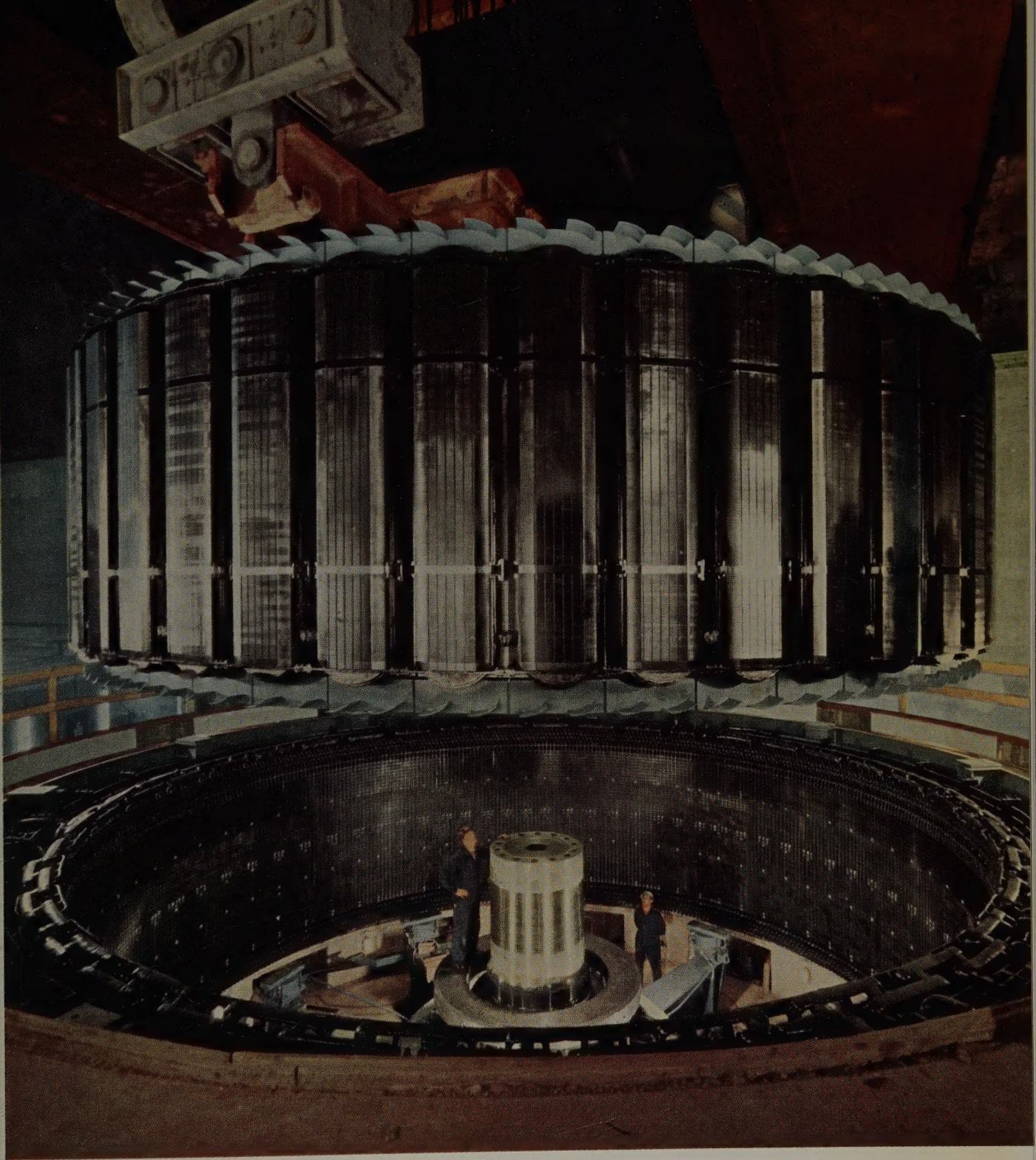




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The 445 ton rotor for one of the three 150 MVA generators at Stornorrfor being lowered into the stator. (F 440, Photo Ekholtz)



Fig. 1. Map showing the Ume and Vindel rivers with their catchment area. (Fr 839)

development, the total flow of $600 \text{ m}^3/\text{s}$ (21,000 cu. ft/s) is divided up over three generators, which provide the total rated output of 375 MW. This means that the power-station is the largest hydro-electric station in Sweden. It is because the head is situated at the lower part of the river where there is a great deal of water that Stornorrfor has achieved this position, in spite of the fact that the Ume river is only the fifth largest in Sweden as far as flow is concerned. Work is now in progress with the object of creating a storage reservoir amounting to 1,390 million m^3 (1,820 million cu. yards) in the Ume river, which will give the above-mentioned production of 1,950 GWh. It is calculated that the storage volume in the Ume river can be increased to 4,200 million m^3 (5,500 million cu. yards). There are further possibilities of damming the Vindel river and when these plans have been completed, the intention is that the second stage of building, which will include a fourth set for $200 \text{ m}^3/\text{s}$ (7,000 cu. ft/s), will be carried out at Stornorrfor, and the rated output will then be increased to 500 MW.

CONSTRUCTIONAL DESIGN

The power-station consists (see Fig. 2) of river dams, a headrace canal, the machine house and a tailrace tunnel cut in the rock, as well as a short tailrace canal.

A spillway dam has been built across the main course of the river, and, in addition, there are two dams across the two side-branches. The combined discharge capacity of the spillway is $3,200 \text{ m}^3/\text{s}$ (113,000 cu. ft/s), which is 14 per cent greater than the maximum known flow of the river. The headrace canal which is 2,400 m (7,900 ft) long, was partly excavated and partly blasted out, and in the latter parts it is more or less square in section being about 20 m (66 ft) deep. There is also a log flume 5,700 m (18,700 ft) long.

The power-station itself is located completely underground having been blasted out of the rock, and its design can be seen from Figs. 3 and 4. The headrace canal runs practically up to the penstocks. The intakes can be closed by means of sector gates and, in addition, emergency closing is provided in the form of needle gates outside the intakes. The station itself consists of the generator hall with the control-room building, the gate shaft and the transformer hall. It will be seen from the illustration that the generator hall is of unconventional design for Swedish conditions, in that there is no floor on a level with the upper edge of the generators. Instead, along the downstream wall of the generator hall there is a balcony which also runs round the generators on a level with their upper edge. The transformer hall also

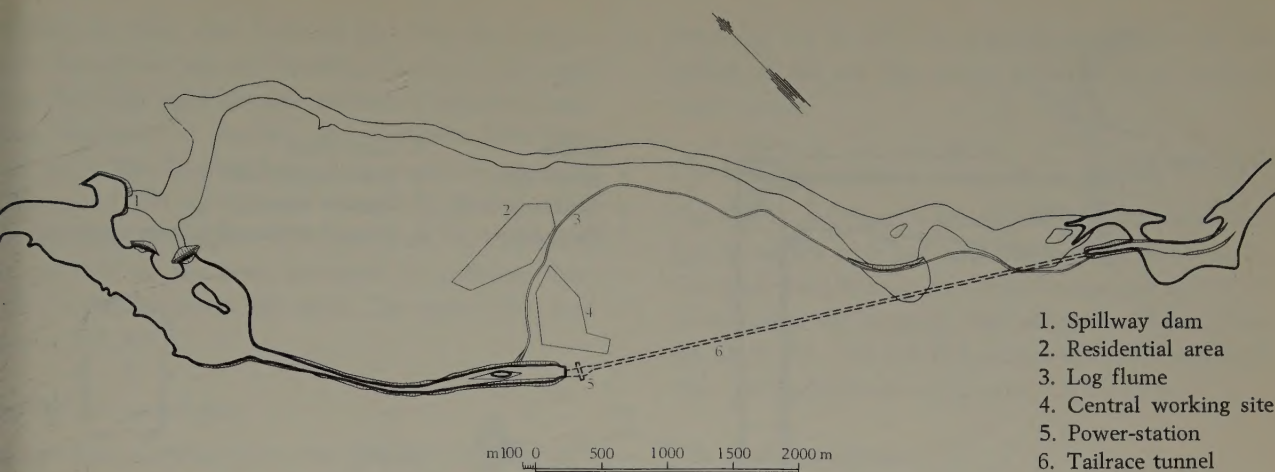


Fig. 2. Plan of Stornorrfor power-station. (Fr 840)

contains the 18 kV switchgear, that is to say, that for the generator voltage. The tailrace tunnel is 4,000 m (13,000 ft) long. It is remarkable in that it has the largest cross-sectional area of any tunnel in the world. The height is 26.5 m (87 ft) and the maximum width 16 m (52 ft), which gives an area of 400 m² (4,300 sq. ft.). At its lowest point, the tunnel is 60 m (197 ft) below sea level. The tunnel was driven in three stages, a top heading of 160 m² (1,700 sq. ft) first, and two benches of 120 m² (1,300 sq. ft) afterwards. It was driven simultaneously from the upstream end and from the tailrace end, as well as in both directions from a central access shaft.

Adjoining the generating station there is a surge chamber which connects with the tailrace tunnel. The draft tubes can be shut off by lowering a gate. There is, however, no shut-off device at the downstream end of the tunnel, and, if necessary, an earth coffer dam will be built right across the tailrace canal. The Swedish State Power Board has been ordered to set up an electric fish-barrier outside the mouth of the tailrace canal and this has recently been done.

The amount of rock excavated from the tunnel amounted to 1.52 million m³ (1.99 million cu. yards) and from the headrace canal 0.65 million m³ (0.85 million cu. yards). In all, the theoretical quantity of rock blasted out for the entire station amounted to 2.75 million m³ (3.60 million cu. yards). The amount of earth excavated was approximately the same, that is, about 2.7 million m³ (3.53 million cu. yards). The quantity of concrete used amounted to 60,000 m³ (78,000 cu. yards).

GENERATOR SETS

The three generator sets in the power-station are driven by vertical single-runner Francis turbines. The normal output contracted for is about 135 MW per turbine with

a head of 75 m (246 ft) and a flow of 200 m³/s (7,000 cu.ft/s), and the maximum output with the same head is about 147 MW. The speed is 125 r/m.

It was also considered whether Kaplan turbines should be used, in spite of the fact that, as a rule, Francis turbines had previously been used in the case of heads of this height, in those cases at least in which the flow of water was as great as at Stornorrfor. It was even found that Kaplan turbines could compete economically. However, the decisive factor in favour of Francis turbines was that Stornorrfor will be used for frequency regulation, and Francis turbines have previously given good results in this respect. Naturally the fact was also taken into consideration that Kaplan turbines of this size had never previously been designed for such high heads.

When the turbines were manufactured, certain new methods were adopted. Thus, to a very great extent, welded designs were used instead of the previous castings. The runners, which weigh 70 tons each, were manufactured at Trollhättan. They were taken by boat to Holmsund and from there by lorry to Stornorrfor. It would not have been possible to have transported the runners by train in one piece.

The rotor of the generators is directly connected to the turbine shaft and is designed with a combined thrust and guide bearing under the rotor and a guide bearing above it. The generators have air cooling with a closed-circuit cooling system and water cooling for the circulating air. The generator output is 150 MVA per set at P.F.=0.9. The generator voltage rating is 18 kV. See the article on page 9 for further details.

OTHER ELECTRICAL EQUIPMENT

Circuit diagram

A single-line diagram for Stornorrfor power-station is shown in Fig. 5. As a supplement to this single-line diagram, Fig. 6 shows a three-pole circuit diagram for the

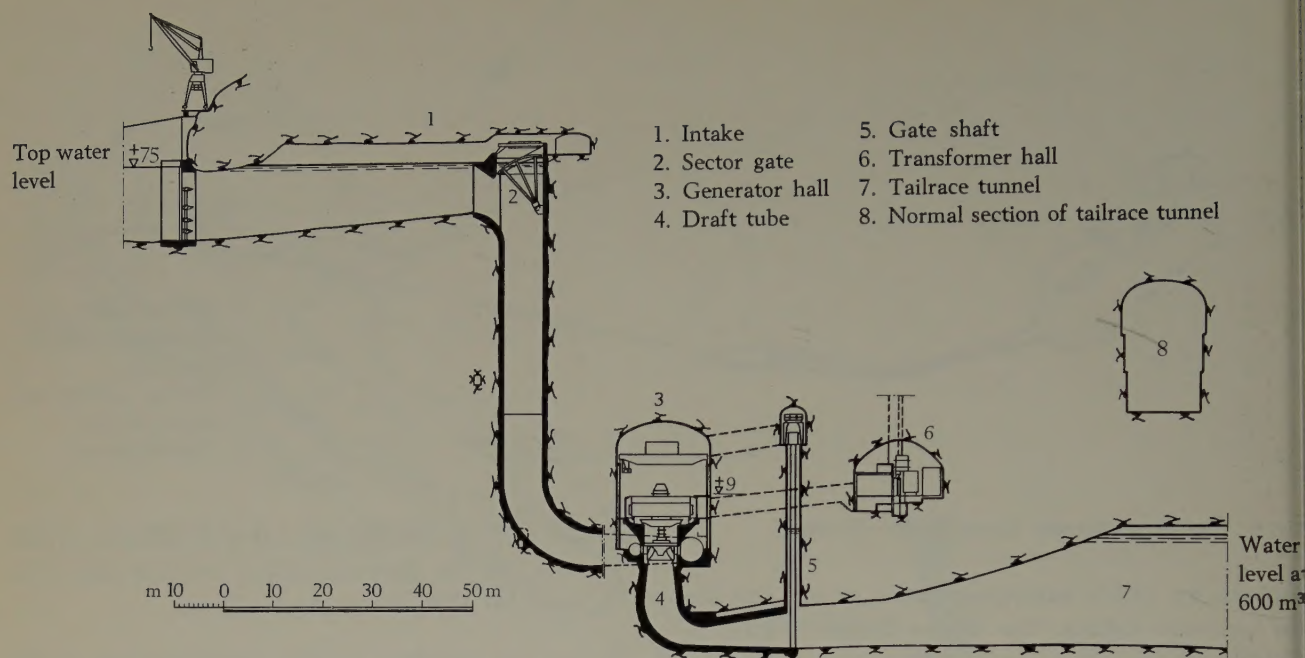


Fig. 3. Vertical section through the power-station. (Fr 841)

transformation of the generator voltage of 18 kV to 400 kV.

Transformers

The major part of the generator output is transformed to 400 kV via a transformer bank consisting of 200 MVA single-phase units with a ratio of $18/\sqrt{3}/400$ kV. Four units are installed, of which one is a stand-by. The three-phase output is thus 600 MVA, which means that the transformation is designed for four sets. The winding for the generator voltage is divided up into two parts, each designed for half the output and intended for the connection of two sets. By this means, a certain limitation of the short-circuit power on the generator side is achieved while, at the same time, the load current becomes more easy to handle. On the 400 kV side, the transformers are designed for direct cable connection. The transformers are water-cooled and their weight amounts to 225 tons per unit. The transformers will be described in greater detail in the next number of the Asea Journal.

For feeding the local 40 kV network in the surrounding district in which Umeå town is the most important sector, there are two 60 MVA transformers with a ratio of 18/45 kV. For the power supply of the station itself, there are two auxiliary transformers, each rated at 2 MVA, with three windings and with a ratio of 18/11/0.4 kV. In addition, there is an auxiliary transformer for stepping down the voltage from 40 kV. Its rating is 4 MVA and the ratio is 44/11/0.4 kV.

The 18 kV switchgear

As has been mentioned above, the 18 kV switchgear is divided up over two busbar systems. As will be seen from Fig. 5, the two systems will be exactly similar when the fourth set, G4, is installed. A maximum symmetrical three-phase short-circuit power of about 5,000 MVA has been assumed. The two-pole circuit-breakers for the 400 kV transformers have a rated breaking capacity of 100 kA, which means full breaking capacity. Because of their position in the system (Fig. 6), these circuit-breakers have less difficult breaking conditions than the other circuit-breakers, which are of the three-pole type. The latter circuit-breakers are not designed for the full breaking capacity, and are therefore protected in such a way that the two-pole circuit-breakers are tripped before the three-pole circuit-breaker in question if the short-circuit current exceeds the rated rupturing capacity of the latter. All the 18 kV circuit-breakers are of air-blast type.

A special feature is that the auxiliary transformers are connected to the 18 kV system via ordinary isolators without any breaking devices. To use circuit-breakers here would have entailed an unreasonably high cost for the switchgear cubicle in relation to the costs for the transformer which was connected to it. The isolators, which have motor operating gear, can break the no-load currents. They can only be operated from the control-room, thus eliminating the risk of injury to personnel in the event of faulty operation. In the case of a fault in an auxiliary transformer, all the circuit-breakers on the same system are tripped. The 18 kV switchgear is of entirely new design. The insulators have been placed

between the bars thus ensuring that the short-circuit forces do not set up any bending stresses in the insulators, but only axial stresses. Instead of porcelain insulators, insulators of araldite with a quartz filler have been used. The busbars have a cross-sectional area of 500 mm^2 (6.98 sq. in.) and the phase spacing is 900 mm (35 in.). The radiation of heat from the busbars to the ambient air has been increased by painting them with a specially tested red paint. The permissible load current is 6,300 A.

The 400 kV switchgear

The station is connected to the 400 kV network via a single radial line and no change is anticipated in this respect for a considerable time. On the 400 kV side, therefore, the station has only been equipped with a single, three-pole circuit-breaker. There is no spare circuit-breaker at the station for which reason the 400 kV circuit-breaker has to be by-passed in the case of a fault or for inspection and service. Because of its limited scope, the 400 kV switchgear has been designed in a specially simplified form. The circuit-breaker is of airblast type and has a breaking capacity of 13,000 MVA. The connection between the 400 kV transformer units and the switchgear consists of four single-phase 400 kV cables. At the upper cable ends isolator switchgear is provided for connecting up the stand-by unit.

The 400 kV cables are designed for a service voltage of $500/\sqrt{3} \text{ kV}$ and are of insulation class 1,600. Their cross-sectional area is 405 mm^2 (0.63 sq. in.) and they can withstand a continuous load of 1,600 A. They are oil-

filled and are fitted with a circulating system for the cooling of the oil. This latter is cooled in an external water cooler.

The 40 kV switchgear

The 40 kV switchgear is actually 130 kV outdoor switchgear in which each bay now houses two 40 kV units. The object was to simplify a future transition to 130 kV on certain of the outgoing lines which now have a voltage of 40 kV. The circuit-breakers are of oil-minimum type with a breaking capacity of 1,500 MVA.

The control equipment

The control equipment is designed in accordance with present-day practice, but contains some special features described below, and which were mainly called for because of the design of the switchgear equipment. In the case of a fault on the 18 kV system, in which the breaking capacity of a three-pole 18 kV circuit-breaker would be exceeded, the tripping of the three-pole circuit-breaker is blocked until the 400 kV transformer has been isolated from the 18 kV busbar in question by the tripping of the two-pole 18 kV circuit-breaker. A fault on any of the two 18 kV auxiliary transformers gives rise to a tripping impulse to all the circuit-breakers connected to the 18 kV busbar in question. If, when the 400 kV circuit-breaker is by-passed, a fault occurs which would normally have caused a tripping impulse to be transmitted to the circuit-breaker, this impulse is transmitted instead to the circuit-breaker at the other end of the 400 kV line. The impulse is transmitted by means of

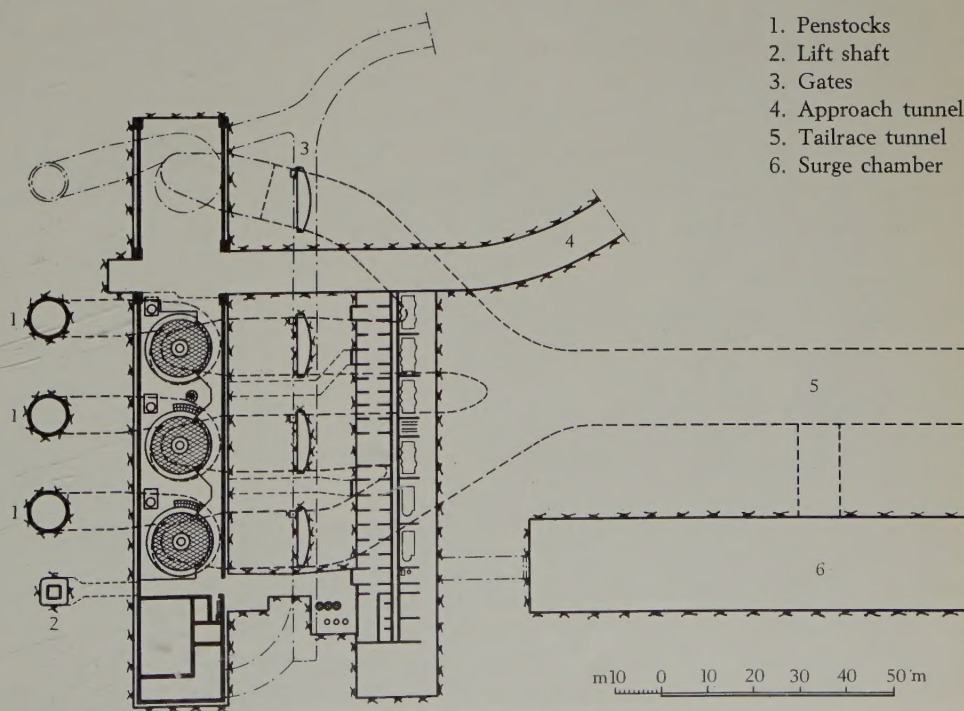


Fig. 4. Horizontal section through the power-station. (p. 842)

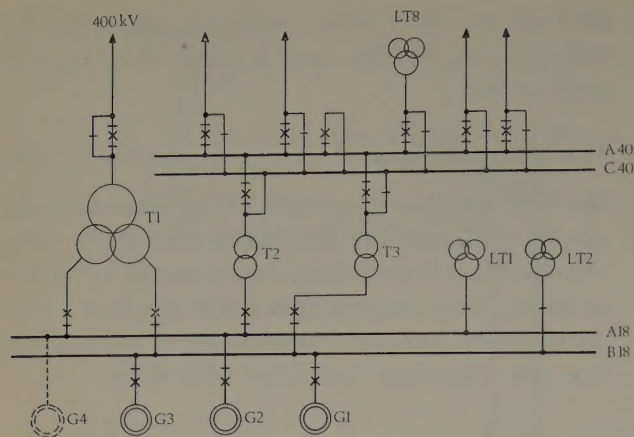


Fig. 5. Single-line diagram. (Fr 843)

carrier current over the 400 kV line. It may be mentioned here that all the tripping impulses to each circuit-breaker have been concentrated in a special tripping panel from which tripping of the circuit-breakers in question can be carried out. The control equipment will be described in greater detail in a future number of the Asea Journal.

Other equipment

For the auxiliary power requirements in the station, a supply network at a voltage of 3×380 V having a neutral with a highly resistive earth is provided as well as a network at a voltage of 380/220 V having a directly earthed neutral, which is mainly intended for lighting. A 10 kV auxiliary system is also available for feeding more distant loads such as intakes, spillways and outdoor switchgear. The 380 V network of the power-station is fed from the two 18 kV auxiliary transformers. All three auxiliary transformers are connected to the 10 kV system, thus ensuring that the power-station can also be fed from the 40 kV system via the 18 kV auxiliary transformers.

The compressed-air system has two compressors which maintain two storage tanks at a pressure of 30 atmos-

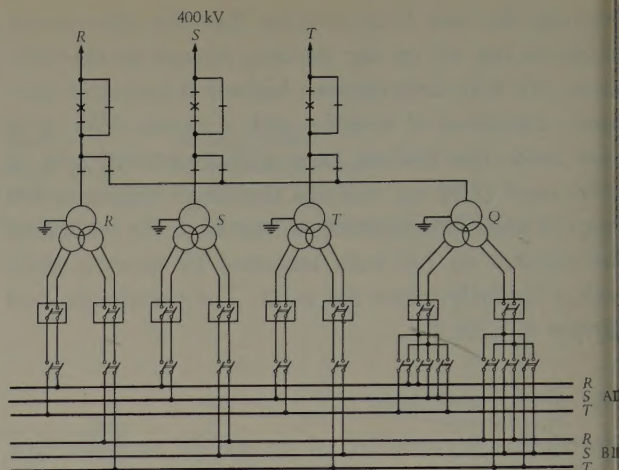


Fig. 6. Circuit diagram for the transformation from 18 kV to 400 kV. (Fr 844)

pheres. The various compressed-air systems are fed from these tanks. The system for the 400 kV circuit-breaker is fed via an electromagnetic valve. The pressure in this system is regulated in that the magnetic valve is controlled by a pressure gauge.

The permanent fire-extinguishing equipment consists of automatic CO₂ extinguishers for the generators and combined water and foam extinguishers for the transformers. The high head of water provides adequate pressure for the fire hoses, without pumps. However, a petrol-driven emergency fire pump is kept in reserve.

COSTS

The total cost of the entire installation has been calculated to be 217 million Sw. kr., of which 31 million Sw. kr. represents the cost of the electrical equipment. On the basis of the rated output of 375 MW, the cost amounts to 580 Sw. kr./kW, which is a low figure. By way of comparison it may be mentioned that Grundfors power-station, which was the last power-station built with 400 kV transformation, costed 1,000 Sw. kr./kW on a similar basis.

THE 150 MVA GENERATORS AT STORNORRFORS

Asea Strömberg, Machine Design Department, Västerås

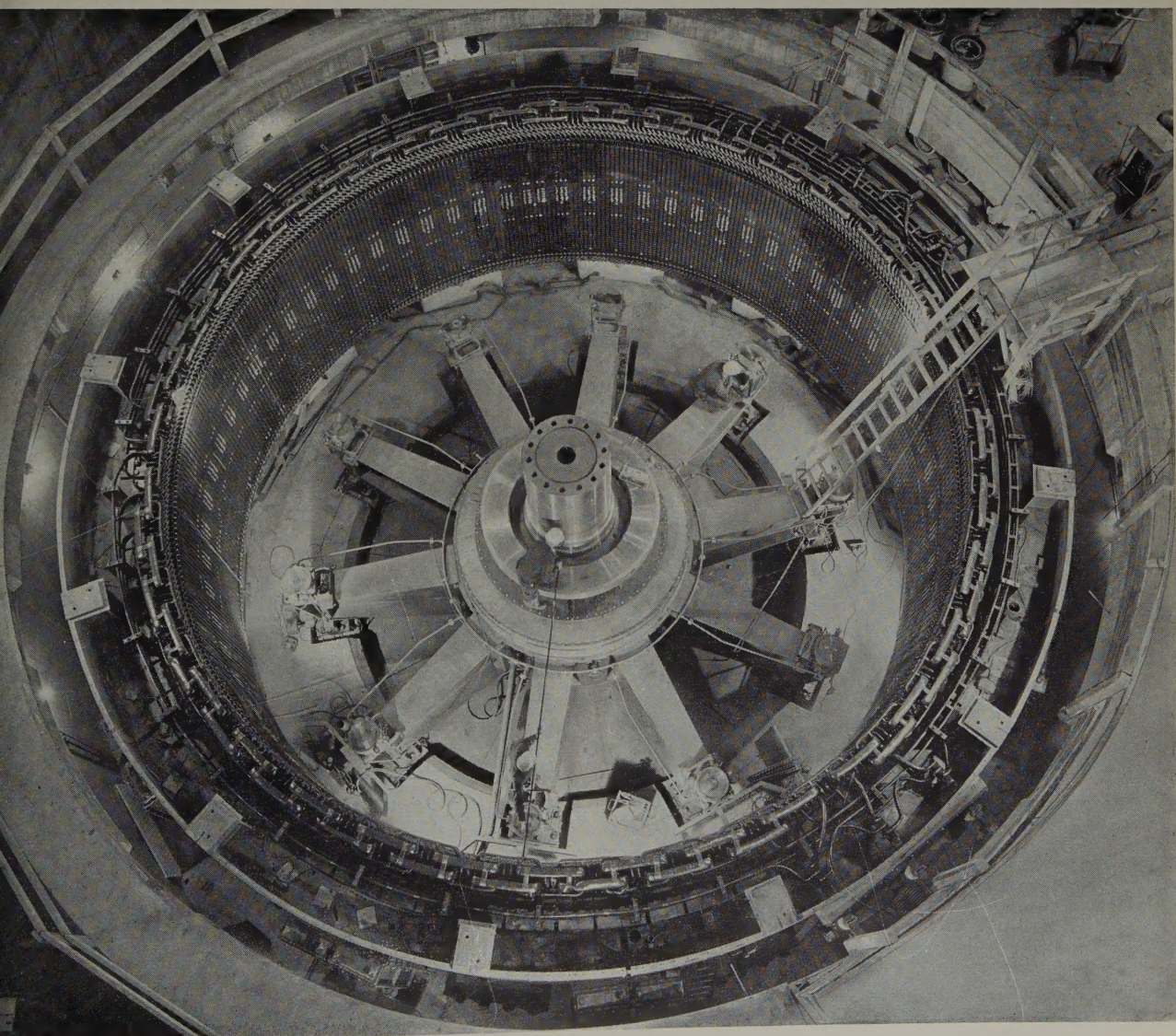
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The generators at Stornorrfor, which have the highest rating of any water-wheel-driven generators in the world at the present time, are described and are compared with the 105 MVA generators at Harsprånget. Interesting new features in the design are dealt with in detail. The influence on the design of the evaluation of the reactances and the losses is discussed.

It seems natural when describing the generators at Stornorrfor to begin by comparing them with the gener-

Fig. 1. The lower bearing bracket with thrust bearing and shaft set up over the turbine pit in the power-station. The arms rest on special foundations, and the brake pads can be seen at the extremities of the arms. The thrust bearing is designed for a load of 960 tons. The stator, which is made up of six parts, is complete. (52179. Photo Ekholtz)

ators at Harsprånget. When they were taken into service in 1952, the latter were among the largest in the world, as far as their rating of 105,000 kVA at 16 kV and their speed of 167 r/m were concerned. The generators at Stornorrfor, which have a rating of 150,000 kVA at 18 kV and a speed of 125 r/m, were, when they were taken into service in 1958, the largest water-wheel-driven generators in the world, as far as output was concerned. As has already been pointed out in the description of the Harsprånget generators [see Asea Journal 26(1953):3-4, pp. 30-42] care must be taken when making comparisons. The output and speed form suitable bases for comparison. In the lower speed ranges, it is possible to build machines for a greater output than in the higher speed ranges; the present discussion is,



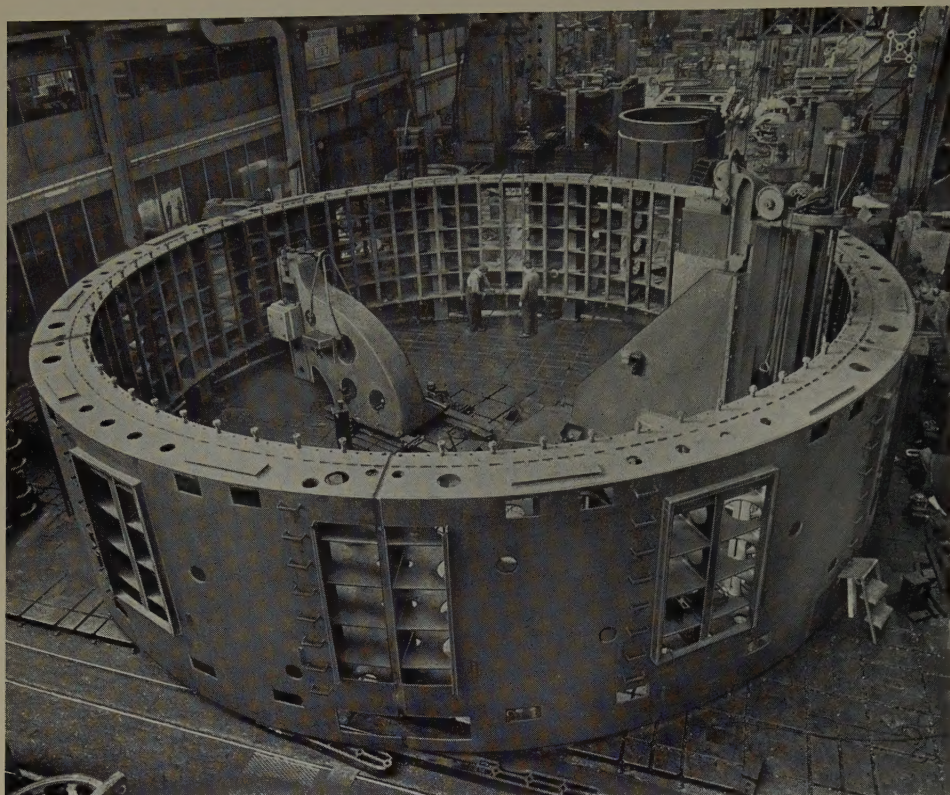
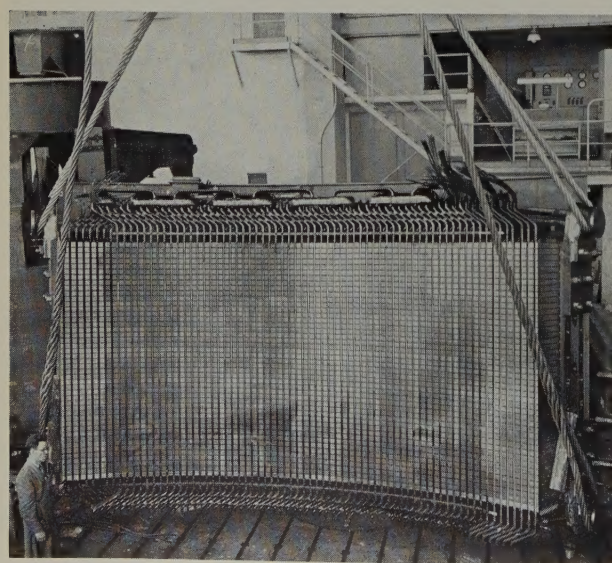


Fig. 2. The stator frame being turned on the floor lathe in the factory. Because of the unusual perspective (the photograph was taken from an overhead crane) the large dimensions have become particularly apparent. Note the two men standing inside the stator. (49907)

of course, entirely concerned with water-wheel-driven generators. The record figure of 150 MVA at 125 r/m will doubtless soon be exceeded. Machines with a greater output are already being manufactured elsewhere, and machines with a lower output but which, because of a lower speed, have greater dimensions and total weight are already in service. Nevertheless, the

Fig. 3. One sixth of a stator, weighing 44 tons, ready for transport to the packing department. Special lifting devices have been fixed to the stator. The coils left out of the stator sections were later inserted at the power-station. The coil ends are braced in the normal way. (51003)



achievement of building the record-size Stornorrfor generators has been of the utmost importance to Asea, and our resources impose no sort of limit on these values. Considerably larger machines have, in fact, already been planned.

It was pointed out in the description of the Harsprånget generators that they form part of a continuous development which led quite naturally to the building of machines of this size. There was a considerable increase in

Fig. 4. An 18 kV stator coil ready for pre-pressing. Although the coil is heavy, it can be handled in this way because of the excellent binding with the aid of epoxy resin, glass fibre and fibre-glass tape. (49946)



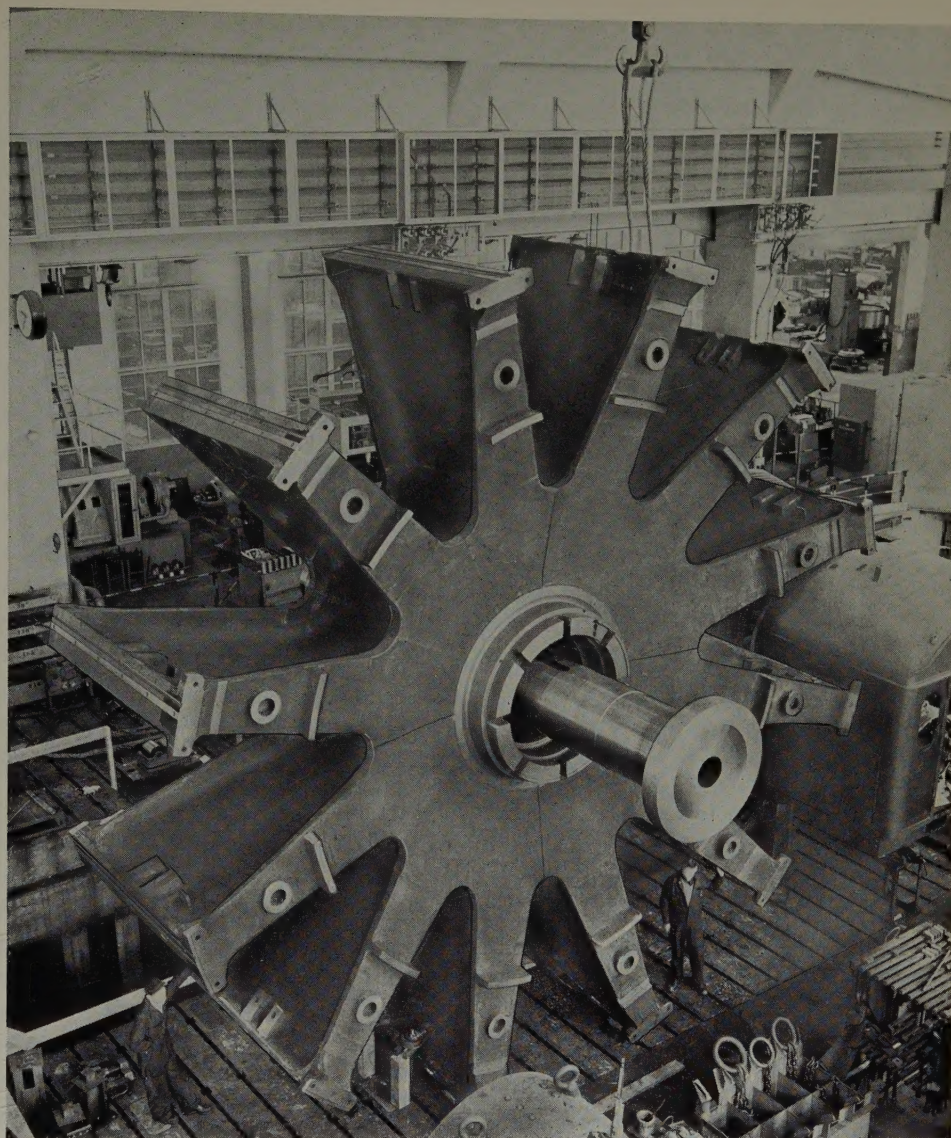


Fig. 5. The rotor spider with twelve arms consisting of four parts held together by bolts and shrink-rings (not yet in place). Weight 8 tons. (50428)

size, but not in the degree of difficulty of manufacture. Furthermore, the following more important features contributing to the development were set out: The building up of the rotor rims from sheet-steel segments in the power-station, the development of insulation for high-voltage windings, the use of axial fans for the ventilation of long machines and the development towards ever larger thrust bearings.

The increase in dimensions—as between the generators for Stornorrfor and those for Harsprånget—was relatively small. The increase in the diameter of the rotor was 16 per cent. The dimensions were mainly determined by the low value of the transient reactance. The main development in the seven years between the design of the two types is the adoption of a considerably higher air-gap density which makes the selection of more economical dimensions possible. The magnetic circuits had to be designed with radically different dimensions in order to prevent an excessive increase in the iron losses.

This improved the balance of the dimensions and eliminated the previous unnecessary generosity as far as the temperature rise was concerned. The transient reactance is guaranteed to be 22 per cent, the same value as that calculated for the Harsprånget generators. If designed in the same way as the latter, the present ones would have to have been 37 per cent larger. If, on the other hand, the transient reactance could have been allowed to amount to 30 per cent, a smaller type of generator could have been selected. It was possible to achieve the low value of 65 per cent for the synchronous reactance without increasing costs to any considerable extent.

A decisive factor when selecting the dimensions was not only the low value of the transient reactance which was desired, but also the evaluation of a deviation from this value which was given. It is obvious that this evaluation had to be supplemented by an evaluation of the losses since a machine with low reactance tends to have high losses, particularly no-load ones. This is an ex-

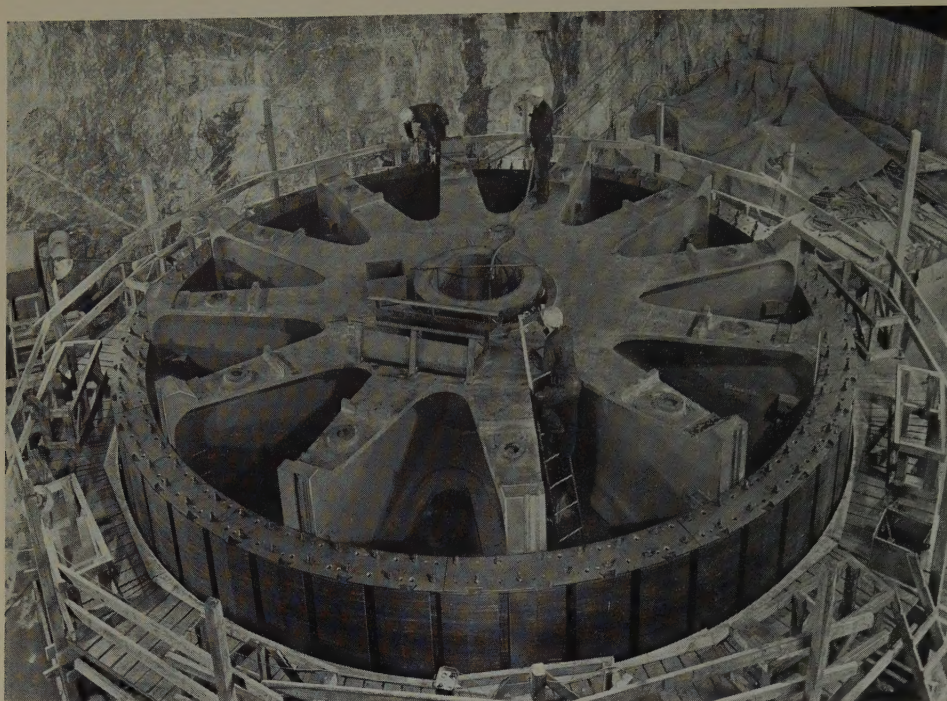


Fig. 6. Stacking the rotor rim in the power-station. The rim, which has twelve segments around its circumference, has a total weight of 240 tons. The illustration shows the stampings being pressed together. This process is carried out continually during stacking. (52189. Photo Ekholtz)

tremely interesting question. It is sufficient here to mention that, during recent years, the selecting of the balance between evaluation of losses and evaluation of reactance has undergone a considerable change which, to a very great extent, influences the choice of dimensions and consequently also the weight, losses and prices. The lower evaluation of reactance which the Swedish State Power Board now applies has a favourable effect on dimensions both from the point of view of the manufacturer and the user.

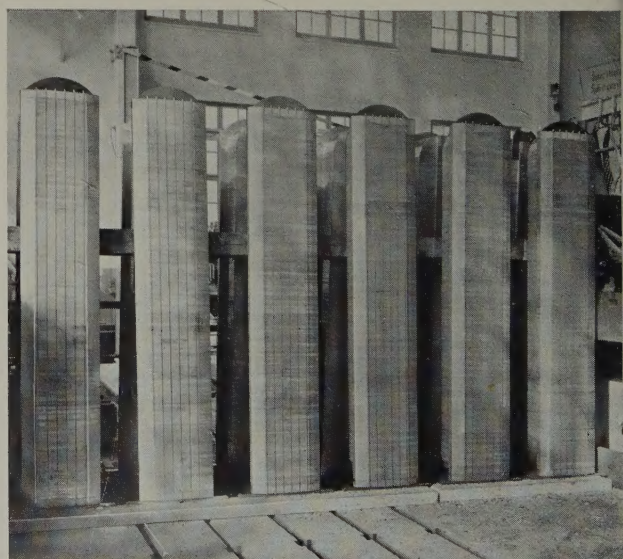
THE DESIGN OF THE GENERATORS

The design is the accepted one for large, low-speed, vertical-shaft, water-wheel-driven generators. The thrust bearing, which is combined with a guide bearing, is located under the rotor. The 10-armed bearing bracket rests on its own foundations, while the load of the stator is transferred to the ground by means of special foundations which are located further out, as will be seen from Fig. 1. Above the rotor there is a light upper bearing bracket carrying the upper guide bearing as well as the exciter, slip-rings and pendulum generator. The generators are placed along one wall of the power-station and are surrounded by a ring of concrete which provides an air duct around the stator. The ventilation system is a closed one and hot air is not extracted for heating purposes. Twelve coolers are distributed around the circumference of the stator.

Fig. 2 shows the stator frame being turned in the oldest bay in the factory for large machines at Västerås. The unusual perspective (the photograph is taken from an

overhead crane) accentuates the large dimensions in its own way. For ease of transport, the stator is divided up into six parts, each weighing 44 tons. One of these parts is shown in Fig. 3 which also demonstrates how lifting is carried out with the aid of special lifting devices. The bracing of the stator coils can also be seen from the illustration. Although the coils are large in themselves, with reference to the short-circuit stresses their dimensions are very reasonable, and bracing presents no difficult problems. The coils left out of the stator section were inserted in the power-station itself.

Fig. 7. Six rotor poles set up for the soldering of the short-circuit rings in the damping winding to the damping bars. The poles are built up of sheet steel with end pieces of cast steel. (51453)



THE STATOR WINDING

The voltage is 18 kV, which was the lowest acceptable value from the point of view of current limitation. The rated current is, in any case, 4,810 A. Asea have already built several 18 kV and 21 kV machines. The insulation is built up of mica tapes impregnated with asphalt compound. There were, however, two interesting new features. Some years ago, for high-voltage windings with large coil dimensions, Asea introduced strand insulation of fibre-glass in combination with epoxy resin, which adheres the glass fibre extremely well to the copper and, in addition, binds the strands together very satisfactorily. This binding is reinforced by painting epoxy resin on to the coil, winding with fibre-glass tape and hardening in hot presses. This gives the heavy coil the correct shape and it becomes rigid and strong. It can be handled as shown in Fig. 4, and the strands are fixed laterally so that displacement is completely avoided. It may be added that the entire process of insulation including the winding on of the tape, painting with varnish, impregnation, pressing and bracing requires unceasing care if quality is to be kept at a peak. Daily co-operation between the workshops and the laboratories ensures this.

The other new feature is the use of a new non-linear protective varnish outside the slots to prevent corona. In the slots, the previous type of protective varnish is used for this purpose. The new varnish outside the slots gives virtually linear voltage distribution. An attempt has always been made to achieve this, but with the types of varnish previously in use it has been difficult to achieve. Tests have shown that the corona protection is very satisfactory. The varnish, which is patented, was developed and thoroughly tested in the Asea laboratories.

As far as the voltage test for the stator winding is concerned, it may be worth mentioning that the contract prescribed testing with a direct voltage of 68 kV and not a.c. test. For several years now, Asea have used direct voltage in its own checking of coils during winding. This means the obviation of the very troublesome sparking

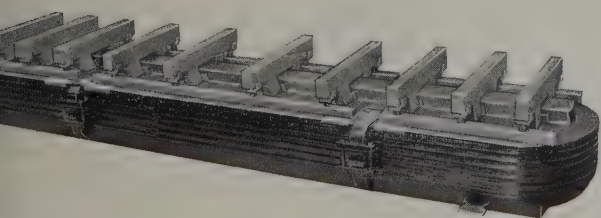


Fig. 8. A complete pole with the field coil ready for de-attach. The coil is kept together under great pressure by means of special supports to avoid changes in its height during transport, and therefore, the coil fits exactly when put into place. (51038)

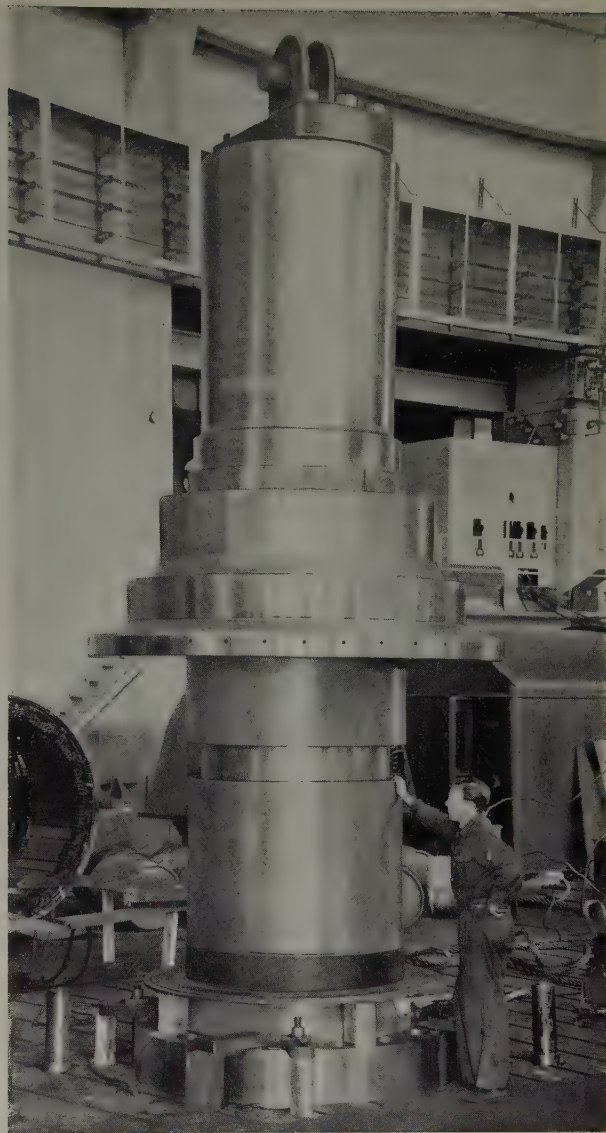


Fig. 9. The main shaft with the thrust bearing runner. Diameter 1,150 mm (45 in.), flange diameter about 1,900 mm (75 in.), weight 57 tons including the thrust bearing runner. (51659)

from the coil ends to the copper strands which are not insulated at this stage and which occurs when a high alternating voltage is used. When the windings are completely insulated, they are normally tested with alternating voltage. Developments in recent years have caused the Swedish State Power Board to modify their regulations, and now, both alternating-voltage tests and direct-voltage tests are to be carried out. Thus, the last generator for Stornorrfor was also subjected to the standard alternating-voltage test in the workshops.

THE DESIGN OF THE ROTOR

The rotor spider, as shown in Fig. 5, has twelve arms as against eight arms in the Harsprånget generators, which is one reason why the weight is as much as 88 tons. Be-

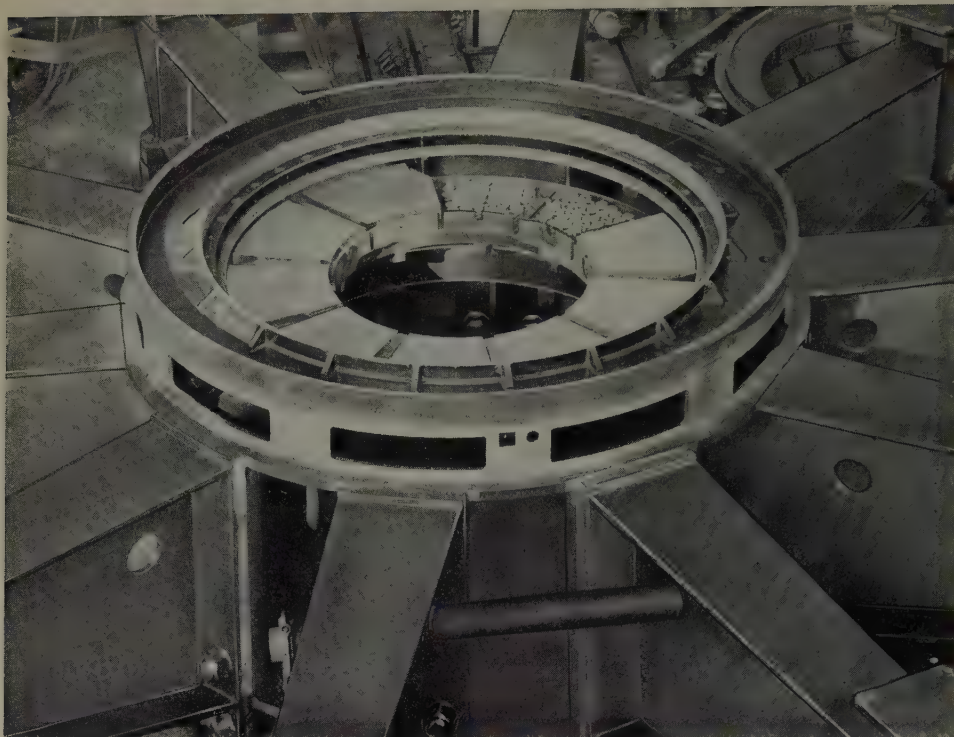


Fig. 10. The lower bearing bracket with thrust bearing being mounted in the workshop. The thrust-bearing segments are carried on sets of springs. The segments can be drawn out radially through the openings in the oil container seen at the end of the arms. (51492)

cause of its weight, the spider is divided up into four parts. With twelve arms, it is easier to build up the rotor rim which consists of twelve segments around the circumference. The resulting rim is more even than previous ones.

The spider is made of cast iron. Before the order was placed, various alternative suggestions for designing the

spider were thoroughly discussed, mainly with the idea of reducing the weight of the rotor. A completely welded design was that which came most readily to mind. Developments have, in fact, since proceeded in that direction. In spite of the capacity of cast iron to take up pressure stresses and the advantage of its having a low modulus of elasticity, only half as great as that of steel, welded designs are lighter and are to be preferred

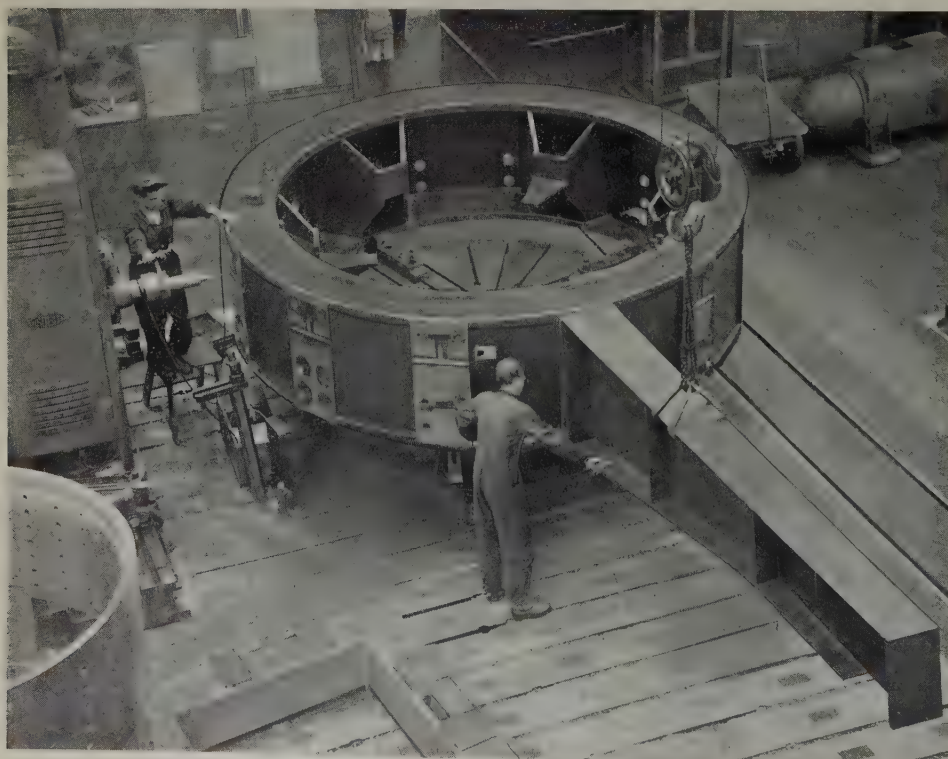


Fig. 11. The upper bearing bracket, the centre and one of the twelve arms. The guide bearing is inserted in the middle. (51490)

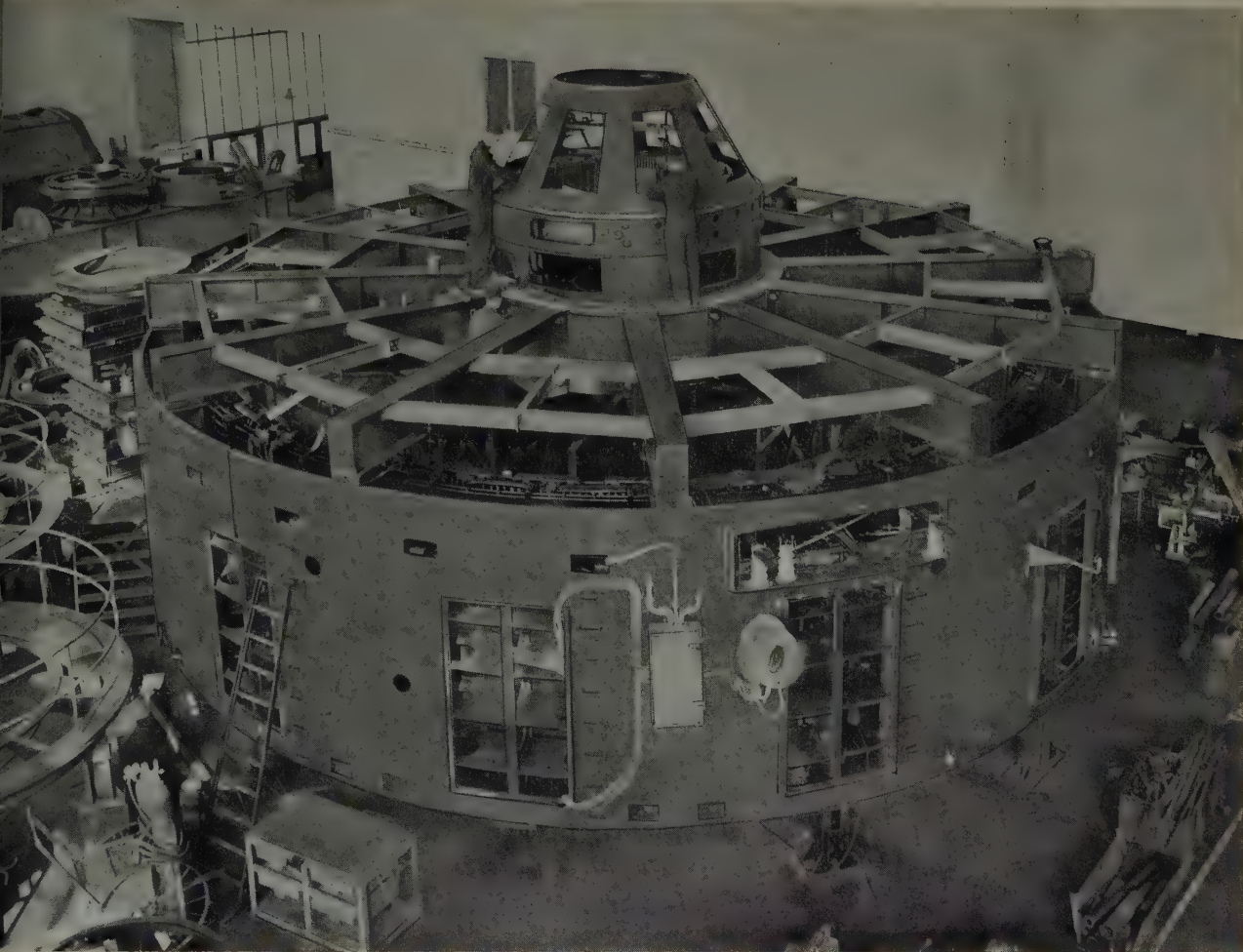


Fig. 12. The stator set up in the workshop for the fitting of the upper bearing bracket, exciter, etc. The new light design of the upper bearing bracket ensures a minimum of machining. (50945)

For other reasons, too. For smaller machines, with rotor diameters up to about 5 m (15 ft), Asea have, for many years, used welded rotor spiders, and very large welded rotor spiders are now under manufacture. However, in between these limits, and for rotors with considerable length, cast spiders are still highly satisfactory.

Fig. 6 shows a rotor rim being stacked in the power-plant. In all, 240 tons of sheet steel are required for the rotor rim. The illustration shows the sheet-steel rim being pressed together before more stampings are added. Finally, the rim is heated to a temperature just over 1000°C. Shrinking wedges are put between the rim and the spider in special slots, and when the rim has cooled, it becomes fixed to the spider with a previously calculated shrinkage force. The shrinkage is so calculated that the rim does not free itself from the spider until speed 80 per cent above the normal is reached. This is probably a higher speed than most other manufacturers adopt.

The poles are built up of sheet-steel stampings and the end pieces are made of cast steel, being held together by means of through-going bolts. Fig. 7 shows six poles set up for hard-soldering the short-circuit ring to the damping bars. A complete pole ready for despatch is shown in Fig. 8. The field coil is braced on the long sides by two braces of non-magnetic steel which go round the pole and are held together by means of a clamp as shown in the illustration. During manufacture, the coil is pressed together at a pressure which exceeds the stresses caused in service by centrifugal forces, and to prevent anything from slipping during transport, a number of fixing brackets are inserted.

SHAFT, BEARING BRACKETS, ETC.

The main shaft (Fig. 9) has a diameter of 1,150 mm (45 in.) and a flange diameter of about 1,900 mm (75 in.), and weighs 45 tons. It terminates at the upper edge of the rotor where a shaft carrying the exciter etc. is jointed on to it. The thrust bearing is fixed to the main shaft. The surface for the guide bearing, and the holes for the circulating oil can be seen.

Fig. 10 shows the lower bearing bracket with the bearing partly built on to it. The ten thrust-bearing segments

rest on springs in the normal way. Other parts are, however, of new design. The oil container and the supports are welded to the bearing bracket. The removal of the segments has been simplified. After the oil has been drained off and a simple lock removed, the segments can be withdrawn through the opening in the oil container, since no other pieces of equipment hinder their removal. The time required for inspecting the segments has thus been reduced.

The upper bearing bracket consists of a large welded centre with twelve arms consisting of welded beams, see Figs. 11 and 12. The design allows of simple adjustment of the upper guide bearing, and is also so designed that machining is reduced to a minimum.

ERECTION

The work of erection has been described previously in the Asea Journal 32(1959):7-8, pp. 99-106. The cover illustration shows a picture of the rotor being lowered into the stator. The rotor weighs 445 tons which is 20

tons less than the weight of the Harsprånget rotor which has a slightly smaller diameter. This is partly due to the higher utilisation of the generator, which is explained by the higher air-gap density, and partly due to the lower peripheral speed at run-away. The difference is not less than 15 per cent, which has a very considerable effect upon the dimensions of the rotor rim.

TESTING

Heat tests and measurements of the losses have been carried out at the power-station. The temperature guarantees stipulate a temperature rise of 70°C on the copper in the stator winding above that of the incoming cooling air. The temperature rise for the rotor windings is 75°C. By adjusting the quantity of air, an attempt is made to maintain these temperature limits as closely as possible, for which reason the ventilation losses, and with them the no-load losses, can be kept at a minimum. The efficiency measured at 150,000 kVA (P.F.=0.9) and 18 kV is 98.19 per cent.

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DISTANCE PROTECTION FOR SINGLE-PHASE OVERHEAD LINES ON ELECTRIC RAILWAYS

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U.D.C. 621.316.925.45:621.332.3
Asea, Reg. 7433

The varying load and the length of the sections of overhead contact line used in electric railways make special demands upon the relay protection. An account of these demands is given and the newly designed Asea distance protection for electric railways, which is available both for 16 $\frac{2}{3}$ c/s and 50 c/s, is described.

During recent years, Asea has developed a series of systems for distance protection which covers most practical requirements. This article describes the distance protection for single-phase electric railways. Distance protection for three-phase grids with various voltages will be dealt with in future articles.

GENERAL REMARKS ON RELAY PROTECTION FOR ELECTRIC RAILWAYS

The demands placed on relay protection for overhead contact lines for electric railways differ in several respects from those normally made on protection for an ordinary three-phase distribution network for the same voltage level.

The relay protection for a three-phase network rated at 10 kV usually consists of over-current protection which is made selective with the aid of varying time delays in accordance with a certain system. The operating time of the relay protection can, at certain points, amount to several seconds. In the case of electric railways, the need for high-speed protection is considerably greater, and it has been increased still further recently, partly because of the increased short-circuit power in the network and partly because of the change-over from aluminium to carbon in the pantographs of the locomotives. The reason for this change of material was the reduction of wear on the contact line and the reduction of interference in neighbouring telecommunication lines. In the case of faults in which the fault current passes from the contact line to the pantograph, there is a risk of the turning of the line when the product of the fault current and the operating time amounts to the order of size of 10,000 As.

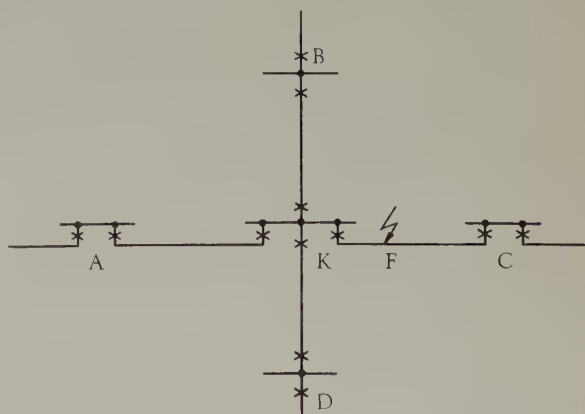
The load on a contact line varies within very wide limits. Sometimes the load can be zero or almost zero, while the load current can, for a very short period, reach extremely high values when several locomotives start at the same time within the same feed section. (In the following, the term feed section is taken to mean that part of the line between two adjacent feed points, converter stations or sectioning stations).

In electric railways, the feed sections are unusually long in relation to the service voltage. The designing of the protection for the contact line is made difficult because the current in the case of a fault at the farther end of a long section may be less than the maximum load current. As a result of the special load conditions, in many cases, use cannot be made of normal over-current, under-voltage, or impedance, relays as protective relays.

Therefore, at a fairly early stage, a sudden-change current relay which functions when the change in current amounts to a set value within a certain short period, was designed for use on electric railways. Experience has shown that this relay provides the greatest possibilities of discriminating between fault current and load current.

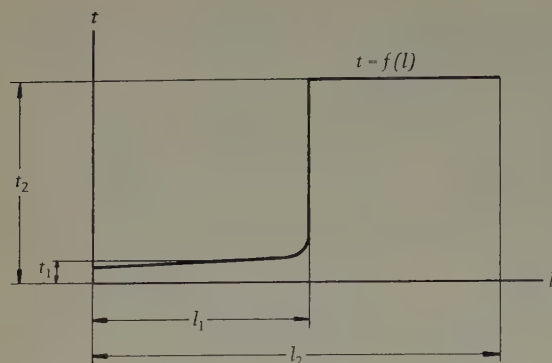
In order to obtain the most rapid tripping possible in the case of high fault currents, the line circuit-breakers are, in addition, fitted with direct-acting over-current tripping. By this means, the total tripping time can be reduced to 30 – 60 m/s (that is to say, 1 to 2 half-cycles at 16 $\frac{2}{3}$ c/s) depending on the magnitude of the fault current and the point on the half-cycle at which the fault occurs.

Since most faults which occur on contact lines are of a transient nature, successful use has been made of automatic reclosing for many years. On Swedish railways, normal practice is to make three attempts at reclosing, the first one after a dead period of about 5 seconds, the second after about 30 seconds and the third after about 3 minutes.



A, B, C and D Converter stations
K Sectioning station
F Location of fault

Fig. 1. Network diagram for single-phase overhead lines on railways. (Fr 799)



- t Operating time of the protection
- t_1 Operating time of the first step
- t_2 Operating time of the second step
- l Distance to the fault
- l_1 Reach of the first step
- l_2 Reach of the second step

Fig. 2. The distance protection has a selective time curve in two steps. The reach of the first step is normally set at about 90 per cent of the feed section. (Fr 800)

THE NEED FOR DISTANCE PROTECTION IN COMPLICATED NETWORKS

For many years, the essential relay protection for contact lines consisted of the above-mentioned sudden-change current relay and direct-acting over-current releases.

As the scope of railway electrification increased, and the overhead contact line network of the railways became more complicated, the adoption of more selective protection than that which can be ensured with the above-mentioned relays became essential. These relays are not directional; thus they may operate for faults lying behind them and they can also, in certain cases, trip for faults which are located beyond their own feed section, which in both cases means non-selective tripping.

In order to improve the voltage conditions in long feed sections without having to set up new converter stations, the Swedish State Railways have, in recent years, built a number of sectioning stations. The contact lines are connected together in these stations at those points where the electrified lines cross each other, and all the lines are fitted with line circuit-breakers, see Fig. 1.

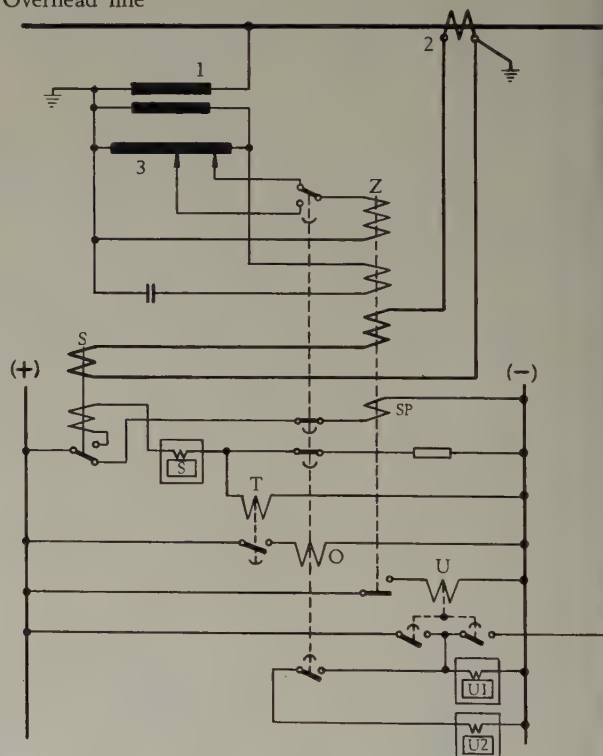
In the sectioning stations, and in the converter stations nearest to these, too, the need for distance protection is particularly acute. For example, if a fault should arise at F in Fig. 1, there is the risk that the circuit-breakers will trip at both ends of all the four feed sections shown. When distance protection is used, only the two circuit-breakers for the section affected by the fault would trip.

Even if station K were a converter station, there would be the risk of eight circuit-breakers tripping in the case of a fault near to K, but since the converters in K cause an increase in the fault current between K and F and

with it an increase in the remaining voltage in K, the risk of the sudden-change relays operating in the healthy lines is reduced. If there are converters in station K, and if conditions are otherwise unchanged, the fault must be considerably nearer K for the relays in the lines without a fault to function than if there is no considerable machine output in K. To put this in more general terms an increase in the short-circuit power at K reduces the risk of the unwanted tripping of adjacent feed sections in which there are no faults. Further, in the case of sectioning stations, sectioning of some of the four lines may be expected, thus increasing still further risk of unwanted tripping of the other lines.

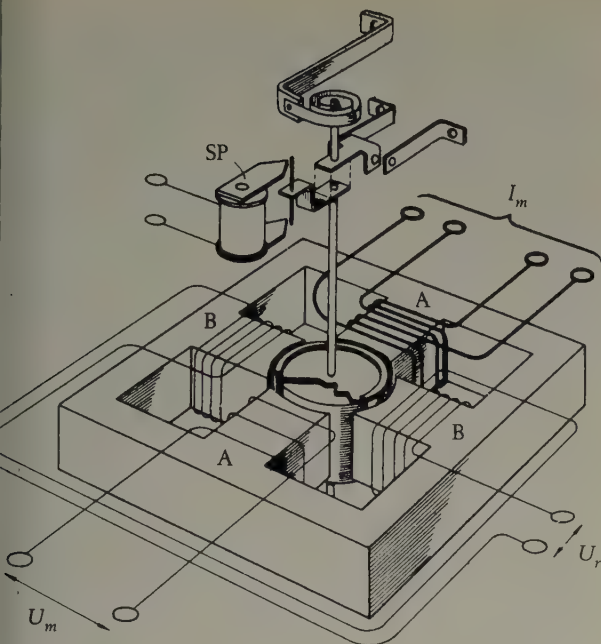
Because of the above, and other, reasons, the Swedish State Railways have introduced distance protection as a standard feature at both ends of those lines which run from sectioning stations, but, on the other hand, not yet generally as line protection for converter stations.

Overhead line



- Z Directional impedance relay
- S Starting relay (sudden-change current relay) with indicating device S
- T Time-lag relay for the time-selection in the second step
- O Auxiliary relay for reconnecting the reach
- U Auxiliary relay for tripping
- U1, U2 Indicating devices
- 1 Voltage-transformer
- 2 Current-transformer
- 3 Intermediate voltage-transformer for setting the reach

Fig. 3. Elementary diagram of the distance protection for single-phase overhead lines on electric railways (16 2/3 c/s). (Fr 801)



Operating current feeding the pair of poles A
 Restraining voltage feeding the pair of poles A
 Reference voltage feeding the pair of poles B

Fig. 4. Diagrammatic illustration of the measuring relay. The contact is supported by a rotatable aluminium drum situated in the air gap between the four poles and the central core. (Fr 802)

DESCRIPTION OF THE DISTANCE PROTECTION

The distance protection has a selective time curve with two steps as shown in Fig. 2. If reserve tripping by means of the starting relay is taken into consideration, the protection may be regarded as having three steps. The principle of the protection circuits can be seen from Fig. 3. Before the mode of operation of the protection is described in greater detail, the two most important elements in the protection – the measuring relay and the starting relay – will be dealt with. The description refers, in the main, to the latest design (type RYZBB) in use on Swedish Railways.

The measuring relay Z consists of an induction-cylinder relay of type RZA. The relay simultaneously measures the impedance and senses the direction.

The relay, see Fig. 4, has a four-pole magnet system. In the air gap between the four poles and a central core there is a rotatable aluminium drum which carries the moving contact part. The electromagnet SP actuates a soft-iron pin on the moving contact part.

When one of the relay poles A is excited by the restraining voltage and the other by the operating current. The two remaining poles B are contained in the reference circuit of the relay which is fed from the voltage-transformer of the line. When the reference circuit and the restraining-voltage circuit are fed by currents in which the

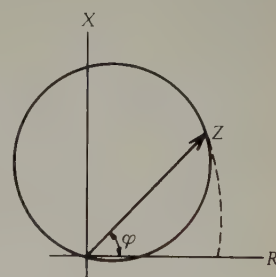
phases are mutually displaced, a torque arises on the relay drum. In the same way, the reference circuit and the operating-current circuit give rise to a torque which, however, operates, in the opposite direction. For certain quotients of the restraining voltage and operating current, the resulting torque on the drum will be zero. The locus of these impedances in an impedance plane with the axes R and X consists of a circle running through the origin, see Fig. 5, and is known as the characteristic of the impedance relay. An impedance vector Z , which represents the line impedance, is plotted in the plane. The relay operates for impedance vectors which fall within the circle while it remains inoperative for impedance vectors which fall outside the circle. In the above-mentioned impedance plane, the connection point of the relay is represented by the origin. The circumstance that the circle runs through the origin thus means that the relay, in addition to its measuring functions, also has a directional effect.

The above-mentioned characteristic applies when the electrical quantities change relatively slowly. However, in the case of short circuits, instantaneous changes are obtained and these give rise to transient conditions in the measuring relay. This means that the characteristic for the first stage is displaced as shown by the dotted line in Fig. 5. This transient displacement is favourable since it increases the ability of the relay to operate for faults with additional resistance which are, in the main, resistive.

In the case of measuring on the second selective step, conditions can, on the other hand, be regarded as sta-

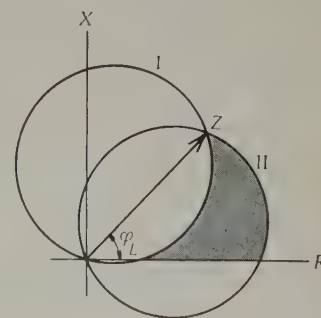
R Resistance of the line
 X Reactance of the line
 Z Impedance vector

Fig. 5. Characteristic of the measuring relay when measuring on the first step. The relay operates for impedances which can be reproduced within the circle. (Fr 803)



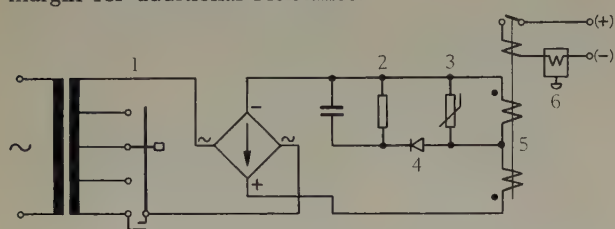
R Resistance of the line
 X Reactance of the line

Fig. 6. Characteristic of the measuring relay when measuring on the first and second steps. The shaded area shows the increased margin for additional resistance obtained by rotating the characteristic downwards when changing over to the second step. (Fr 804)



tionary because the time t_2 has already elapsed since the occurrence of the fault. However, here too, it is possible to obtain a greater margin for the additional resistance by rotating the characteristic downwards in the direction of the R axis. This effect is obtained in that the reconnection relay O short-circuits certain elements in the reference circuit of the measuring relay (not shown in Fig. 3).

Fig. 6 shows the characteristic I, which is the same as that shown in Fig. 5, and the characteristic II, which applies when measuring on the second selective step. The reach of the relay along the line drawn at the angle φ is represented by the vector Z , and the reaches set are thus the same for the first and the second step in the case illustrated. The dark surface shows the increased margin for additional resistance.



1. No-break switch for setting the operating value of the starting device.
2. Resistor for discharging the capacitor.
3. Non-linear resistor which gives the starting device an over-current character.
4. Valve which prevents the starting device from operating when the current is reduced.
5. Relay with two counteracting windings and a hold-in winding.
6. Indicating device.

Fig. 7. Elementary diagram of the starting device. The relay operates when there is a sudden change in the current, or in the case of continuous over-current. (Fr 805)

In order to ensure that the relay operates in the case of faults which are very close to it, when the voltage drops to zero instantaneously, the reference circuit has been designed as a series resonance circuit which can retain a natural oscillation for a sufficiently long period for the relay to be able to determine the direction of the fault. This means that the protection has a reliable directional action for faults which are close to the current-transformer.

The measuring relay can be set for four different reaches (for a length of line of from 4.5 to 36 km) by the choice of a suitable value for the number of turns on the current coil. The reaches quoted are obtained when full measuring voltage is applied to the relay. The reach can be increased and finely adjusted with an accuracy of about 1 per cent by the choice of suitable terminals on the intermediate voltage-transformer 3 in Fig. 3. This setting can be carried out very simply by means of screw-in type plugs on a board, see Fig. 8.

The starting device S is a sudden-change current relay of type RDRA. The principle of operation is briefly as follows, see Fig. 7. The operating current is transformed down, rectified and fed to two counteracting series-connected windings on a relay 5. A capacitor is connected in parallel with the one winding. When a sudden change in the current occurs, at the first moment the capacitor short-circuits the sudden change, for which reason electrical unbalance arises in the relay windings and the relay operates. The starting device can also be made to operate in a simple way for a continuous over-current with the aid of a variable resistor (3 in Fig. 7) connected in parallel with the one relay winding. Power consumption is of the order of size of 5 VA at rated current.

The starting relay S can be set on one of the primary current ranges 175, 200, 225 or 250 A. The normal setting is 175 A. The operating value of the relay for continuous over-current lies within the range 650–1,000 A primary and depends on the above-mentioned setting.

The relay is set by moving a pin in a no-break change-over switch (1 in Fig. 7). If the pin is removed completely, the relay is set at 250 A.

The first step

In the case of a line fault on the first step, the measuring relay Z (see Fig. 3) closes its contact immediately, whereupon the auxiliary relay U operates and gives the tripping impulse to the circuit-breaker, whereupon the indicating device $U1$ operates. Relay U has a certain resetting delay to give the circuit-breaker an adequately long tripping impulse.

For line faults situated within the first step, the protection functions in 30–70 ms (t_1 in Fig. 2). The operating time varies in accordance with a number of factors such as the magnitude of the fault current and the position of the fault. Faults close to the protection with high current give short operating times.

The second step

If a line fault occurs beyond the range of the first step, the contact of the measuring relay will, to begin with, remain in its blocking position. However, the starting relay S operates for the sudden change in current when the fault arises and closes its contact, whereupon the relay is energised via its hold-in winding. At the same time, the time-lag relay T starts and, after a set time, connects in the relay O , which, in its turn, decreases the impressed voltage to the measuring relay by reconnecting the intermediate voltage-transformer. This increases the reach of the measuring relay to the value l_2 and the relay thus operates if the line fault is situated within this reach. When tripping occurs, the indicating devices $U1$ and $U2$ operate.

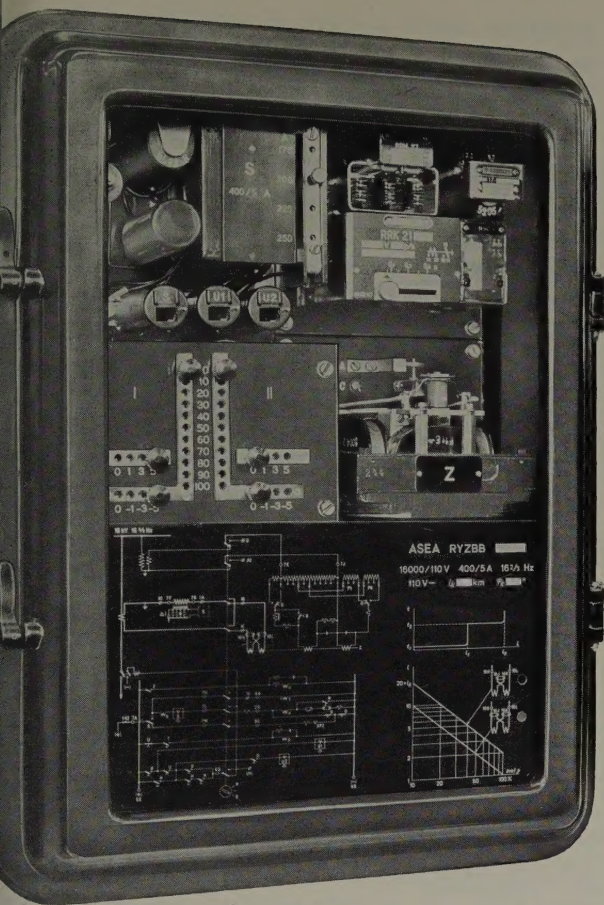


Fig. 8. Asea distance protection for single-phase overhead lines for electric railways ($16\frac{2}{3}$ c/s). At the top, the starting relay and the auxiliary relays can be seen. The board for the setting of the reach can be seen next to the impedance relay Z. The lower part of the protection is covered by a board with the connection diagram marked on it and a diagram for simplifying the setting. (50358)

As has been pointed out above, in certain cases it is not possible to protect a long feed section with an impedance relay alone, since the impedance of the section is greater than the smallest load impedance which may occur. In addition, in the case of overhead contact lines for $16\frac{2}{3}$ c/s, the impedance of the line has approximately the same phase-angle as the load, and it is therefore not possible, as is usually the case in 50 c/s networks, to make use of the fact that the directional impedance relay has its reach increased as the angle φ increases (see Fig. 5) within the angular area in question. Naturally, it is mainly when the range of the measuring relay is extended to the second stage that there is a risk of exceeding the minimum load impedance. However, the risk of accidental tripping is virtually non-existent since, if tripping is to occur, the operation of the sudden-change current relay is also necessary.

Starting and resetting

In the case of all faults which give rise to a sudden change of an adequate size in the current, the starting

relay S functions and guides the reconnection relay O via the time-lag relay T, as described above. When relay O operates, the hold-in circuit for the starting relay is interrupted, whereupon both this and the relays T and O are reset. However, the operation of relay O is delayed by about 0.5 seconds on resetting during which time the measuring relay Z is given the opportunity of measuring on its second step.

The impedance relay Z is fitted with an electromagnet SP which attempts to keep the relay contact in the middle position, applying a certain force. When the starting relay S operates, the lock is disconnected and the impedance relay can measure with great accuracy. The lock is also cancelled by reconnection relay O. When the starting relay operates, indication is obtained in device S.

Over-current tripping

The distance protection is provided with time-lag over-current release. The starting relay is so designed that it also operates for continuous over-current of a certain magnitude. When this occurs, the relays T and O operate in the way described, but the relays do not reset since the starting relay is now able to remain in the closed position because of the over-current. The time-lag for the over-current release is naturally selected longer than for the second step of the protection. The connections required for the over-current release are not included in Fig. 3.

VARIOUS DESIGNS

The protection described above is designed for $16\frac{2}{3}$ c/s and is mainly intended for use under Swedish conditions. Similar protection has been designed for 50 c/s mainly for use in Great Britain, where, within the next few years, a great deal of additional railway electrification is to be carried out. In Britain, use is made of 25 kV and 50 c/s, which is taken directly from the 132 kV three-phase grid by means of single-phase transformers which, on the primary side, are fed from a line-to-line voltage.

The starting and measuring relays in the 50 c/s protection have the same properties as in the $16\frac{2}{3}$ c/s protection. The only essential difference is that the former protection has been fitted with a device for the compensation of mutual impedance from parallel railway tracks. This is because double tracks are normal in Britain. The mutual impedance amounts to about 20 per cent provided that the rails and earth are used as the return. Compensation is achieved in that the starting relay extends the reach of the protection in the parallel track by a corresponding amount. The device selected has a favourable influence on the operating time of the protection, and the result is, on the whole, that the pro-

tection can, while maintaining its selectivity in most cases, trip for faults along the entire line section without having to make use of the second step.

EXPERIENCE IN SERVICE

About hundred protection equipments have been supplied to the Swedish State Railways and, of these, about 50 have been in service for, on the average, three years. Experience has so far been very satisfactory. Because of the considerably reduced number of breaker trippings now obtained in the case of line faults, compared with

conditions which were usual when non-selective protections were used, the wear on the circuit-breakers is reduced to a very great extent, and with it, the maintenance work. Since the frequency of occurrence of faults is high, being considerably higher than in a three-phase network at the same voltage, this alone ensures in the long run, compensation for a large part of the higher costs of the selective relay protection.

The first protection equipments for 50 c/s supplied to customers in Britain were taken into use relatively recently and for this reason no details of experience there can yet be given.

CHANGES WITHIN THE ASEA GROUP

Asea Reg. 907

An agreement has been reached between Asea, Svenska Turbin AB Ljungström and AB de Lavals Ångturbin whereby the latter two concerns have merged their interests to form a joint company for the manufacture of turbines under the name *De Laval Ljungstrom Turbine Co.*

It is estimated that the world demand for steam and gas turbines will be doubled over the next 10 years. In Sweden the demand will increase even more rapidly than in the rest of the world, since by the end of the 1960's the greater part of the hydro-electric power resources within the country will have been exploited and nuclear power plants will be built instead. Since the end of the war, the manufacture of turbo-generators has been concentrated on ever larger sets. In the U.S.A., for example, the average output of turbo-generators for power-stations has increased from 30 MW in 1946 to about 120 MW in 1958. This factor is closely linked with the considerably lower production costs for power from large machines.

The need for larger machines, increased reliability and improved thermal efficiency necessitates an intensified development and research programme as well as greater manufacturing facilities. For this reason, therefore, the manufacture of large turbo-generators is being increasingly concentrated on concerns having comprehensive resources.

The largest international concerns can offer a complete manufacturing programme within the field of turbines, covering not only power-station turbines but also industrial and marine sets as well as gas turbines, compressors and pumps.

The two leading Swedish turbine manufacturers, AB de Lavals Ångturbin and Svenska Turbin AB Ljungström, are both undergoing a period of rapid development.

Nevertheless, it must be acknowledged that many of the competitors have a larger capacity and a more extensive manufacturing programme. In view of the advantageous competitive position of the European Community of the Six, the continued increase in turbo-generator outputs and the development of turbo-generators for nuclear power plants, the two companies in question have decided to amalgamate their interests so as to be able to serve both new and old customers even better than previously.

De Laval Ljungstrom Turbine Co. have an ordinary share capital of Sw. Kr. 30 million, of which AB de Lavals Ångturbin have acquired Sw. Kr. 9 million. A nominal Sw. Kr. 12 million, i.e., 40 per cent, was offered in the first place to Asea's shareholders, while Asea retained a nominal Sw. Kr. 9 million.

The activities of *AB Svenska Fläktfabriken*, covering the manufacture and sales of air-conditioning plants for both industrial processes and buildings, pneumatic transport systems, dust-extraction plants, etc., have reached such a scale and are of such a nature that it was considered natural to separate the company from the Asea Group. Asea therefore offered 68 per cent of the ordinary share capital, or a nominal Sw. Kr. 20.25 million, in the first place to the shareholders.

The operation of power-generating and distribution plants constitutes the main activity of *AB Skandinaviska Elverk*, and it was therefore decided to place a part of the company's shares on the market. Since the company, together with Asea, is one of the majority shareholders of Voxnans Kraft AB, which, in its turn, owns and manages the power-stations and water rights of the Asea Group, Asea have retained, however, a majority of the shares. About 40 per cent of the share capital of Sw. Kr. 30 million, or a nominal Sw. Kr. 12.15 million was offered, in the first place to the shareholders.

N MEMORIAM

SVEN ERIK ERIKSSON

The sudden death of Sven Erik Eriksson came as a great shock to those who knew him. He had seemed to have made an excellent recovery from the days when heart trouble threatened him, and was full of energy and life when snatched away with startling abruptness from family, friends and the company to which he had rendered invaluable service.

He was in every way an exceptional man: in his character decision and ingenuity were nicely blended with modesty and sensitivity, warm-heartedness and humour.

Asea and all those connected with the company owe him a deep debt of gratitude. He piloted Asea's production departments through the post-war crises with extraordinary skill; he reshaped our production techniques – a necessary task, but an intricate and laborious one. At



(Z 8869)

many of Asea's high-level deliberations his wisdom and experience proved inestimable assets.

He will long be remembered for his outstanding leadership and his warm humanity.

NEWS IN BRIEF

ASEA EXHIBITION IN NEW YORK

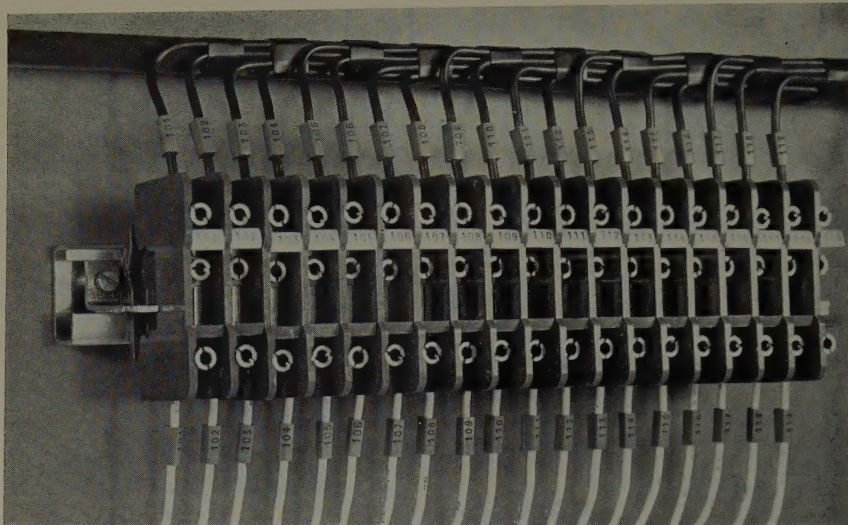
Asea's affiliated company in the U.S.A., Asea Electric, Inc., participated in the Engineering Progress Exposition held in New York on the 17th–20th June of this year. As can be seen from the photograph, the Asea stand included a cut-

away model of a STAL turbine, a model of a deck crane for ships, as well as working models of a mine hoist and a pressductor. In addition, a number of photographs were displayed, showing, for example, the new Asea High-power Laboratory (with the two generators rated at 1,000 and 2,500 MVA, respectively) and the transformer workshop at Ludvika; a pressductor installation for 2,000 tons at the rolling mill of Surahammars Bruks AB; an induction stirrer

for a 150-ton arc furnace at the steelworks of Fabrique de Fer de Charleroi, Belgium; the mine-hoist installation of Luossavaara-Kiirunavaara AB at Kiruna, one of the largest of its kind in the world; a welding set for joining tubes having a max. diameter of 130 mm (5 in.), thickness of material 4.25 mm (0.17 in.); and, finally, a coloured drawing of a 20-MW STAL turbine for Detroit Edison Company. Great interest was shown in the exhibition. Asea Reg. 9547

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TERMINAL BLOCK WITH ISOLATING DEVICE AND TERMINAL CLAMPS OF PIN-BOLT TYPE

The Asea terminal block, type OTFA 46, is of totally new design and is intended to comply with the requirements in the Swedish Standard SEN R 36 03 13, Class B. This implies, amongst other things, that the terminal block can be isolated and has facilities for testing. The break is plainly visible.

The terminal clamps are designed with pin bolts and nuts, since experience with earlier Asea designs of terminal block having the same type of terminal clamp has been extremely favourable.

Terminal clamps of pin-bolt type possess the following advantages:

1. The terminal clamp is visible even when the terminal block is located in an inconvenient place. Faulty connection is thus prevented, especially when two or, exceptionally, three conductors are to be connected to the same terminal.
2. A conductor can be temporarily attached to the pin bolt, e.g., for testing.
3. The conductor will not fall off the pin bolt even if the nut has not been properly tightened.

These advantages outweigh the cost of forming an eye or fixing a cable lug to the conductor.

The nut for the terminal clamp is of slotted barrel design, and it is thus a simple matter to insert banana contacts when making tests.

The body of the terminal block is moulded from a special non-tracking alkyd compound with an inorganic filler and possessing excellent mechanical properties. The end plates are also moulded from the same alkyd compound and are designed so that they can also be placed between the terminal blocks, which results in increased creepage distances. The creepage distances to earth are also more than adequate. The terminal blocks will comply with the regulations for creepage distances given in Lloyd's Register of Shipping, Rules for Electrical Equipment, provided that the end plates are inserted between each terminal block.

Bridge connectors, support bars, marking tags, marking strips and a screwdriver common to the slotted barrel nut and screw for the isolating device are all supplied together with the terminal blocks.

Technical data:

Voltage rating for group I according to SEN 21 06: 600 V, d.c., 500 V, a.c.

Voltage rating for group II according to SEN 21 06: 440 V, d.c., 380 V, a.c.

Insulation class K₁-2.5 according to the above Standard

Test voltage for type tests: 2.5 kV

Current rating: 25 A

Max. conductor cross-sectional area per terminal: $2 \times 6 \text{ mm}^2$

Asea Reg. 5231

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Articles or extracts from this Journal may be reprinted on condition that the name - Asea Journal - is clearly stated.

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